# Bridge End Drains



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This section discusses the location and placement of bridge end drains, and intake grate capacity. The current policy for installation of bridge end drains is as follows:

### Location of End Drains

1. All new bridges should have an end drain installed at each corner located on the down hill end of the bridge to catch water running off the bridge and approaches.
2. All new bridges on superelevated curves should have an end drain installed on the low side downhill from the bridge.
3. On the uphill approach to new bridges when the grade is less than 1.6%, check the direction of the flow in the gutter. If the water flows away from the bridge, an end drain is required.
4. On urban sections with curb and gutter, end drains will not be required. Storm sewer intakes will be located as necessary to take care of drainage.
5. In areas where there is variable width or variable cross slope in the bridge approach section, check gutter elevations to determine direction of flow. If water flows away from the bridge, an end drain is needed.

## Types of End Drains

End drains consist of three types: Standard Road Plans RF-38(1&2), RF-39, and RF-40. The RF-38 (intake) or RF-40 (rock flume) end drain is to be used when the roadway embankment is constructed of erosive soils (e.g. sand, loess) or the embankment exceeds 15 feet (4.5 meters) in height. The RF-39 end drain (sod flume) is to be used when the roadway embankment is constructed of non-erosive soils and does not exceed 15 feet (4.5 meters) in height. Contact the Roadside Development Section in the Office of Design for additional information.

A three-step process is used to determine the location of the Bridge End Drains. This process is identical for English and metric units

1. Determine inlet location. This can be done by hand as shown in the examples below, or in CADD.
2. Compute storm runoff in cfs for the design storm (refer to Sections 4A-1 and 4A-4 of this manual)
3. Determine grate capacity.

### Example 1

Shoulder widths are 6’ and 10’

Skew angle is 30 degrees

Determine the inlet location

The inlet location is a function of various bridge characteristics, the bridge approach section and the placement of the guardrail. The best way to place the end drain is to draw the bridge situation plan, locate the joints in the approach section, and determine the position of guardrail and guardrail posts.

a) Standard Road Plans RF-38, RF-39 and RF-40 show the point from which DI1 and DI2 are measured when using RE-69A or RE-69B. For RE-69C, use the center bolt hole in the bolt hole pattern. Standard Road Plan RE-65A shows the location station to be used for a guardrail installation at a bridge end when using RE-69A or RE-69B or RE-69C.

b) Determine $d_1$ and $d_2$ for the bridge approach. Of the two, $d_1$ is always the shoulder width on the shorter side of the reinforced bridge approach section, and on the side of panels B and C.

c) Determine the skew angle case (see Section 7D-1 of this manual).

d) Panel size is assumed to be 20 feet.

Note that the example gives a minimum requirement for intake location. Intakes can be moved a greater distance from the location station, if desired, but the designer should then verify that:

1. The intake is located approximately in the middle of two guardrail posts.
2. The intake is at a 5-foot minimum distance from the nearest joint and beyond the reinforced bridge approach section.

   If condition 1 or 2 is not met, the designer should extend the guardrail by 12.5-foot increments in the variable tangent section of the guardrail layout, then check the location of the intake at 6.25-foot increments until it meets the requirements.

From b, $d_1$ = 6’, $d_2$ = 10’

From c, this will be a Case 2 situation (see Example 2 in Section 7D-1)

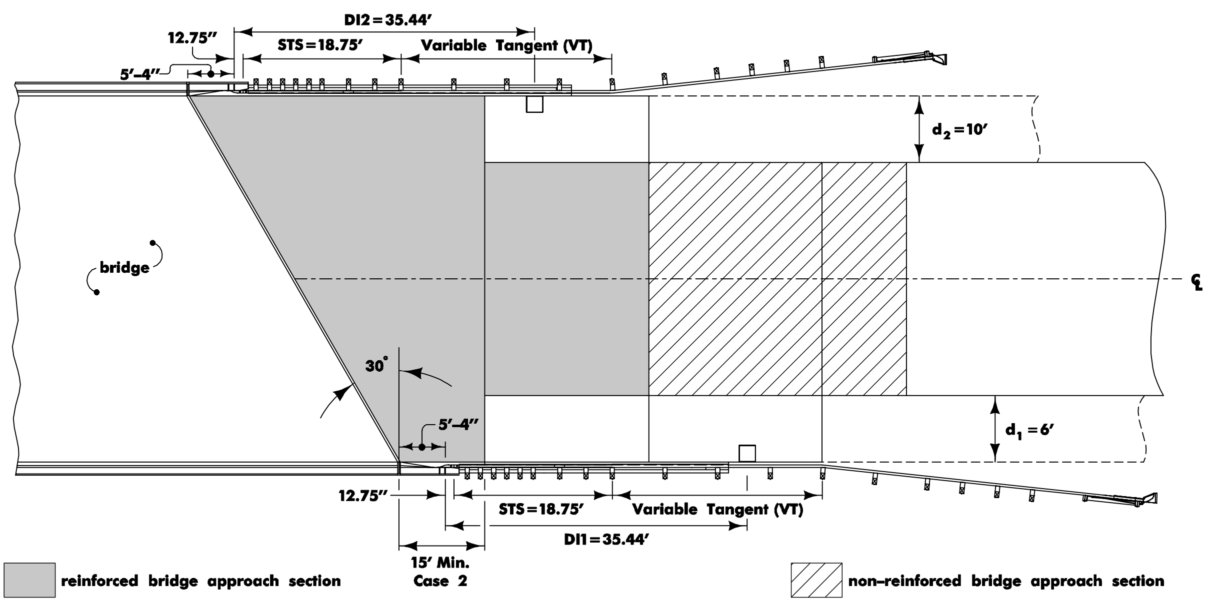


**Figure 1:** Location of the intakes.

In Figure 1 on the d1 side, the joints are located at 5.33 ft., 25.33 ft., and 45.33 ft. from the bolt hole location shown in RE-69A, and 69B, or the center bolt shown in the RE-69C.

DI1= 12¾ in. + 18.75 ft. + 6.25 ft. + 6.25/2 ft. = 29.19 ft., but the intake location is less than 4 ft. from the nearest joint so it does not meet requirement #2. Therefore a variable tangent of 12.5 ft. should be added. Now the location of intake DI1 is 12¾ in. + 18.75 ft. +12.5 ft. + 6.25/2 ft. = 35.44 ft. from the bolt hole location which is more than 5 ft. from the nearest joint and between 2 guardrail posts, see Figure 1.

In Figure 1 on the d2 side, the joints are located at 28.33 ft., 48.33 ft., and 68.33 ft. from the bolt hole location.

DI2 = 12¾ in. + 18.75 ft. + 12.5 ft. + 6.25/2 ft. = 35.44 ft.

## Example 2

Shoulder widths are 10’ and 10’

Determine the inlet location

Skew angle is $10^{o}$

D1 = 10’

D2 = 10’

This will be a Case 1 situation (see Example 1 in Section 7D-1)

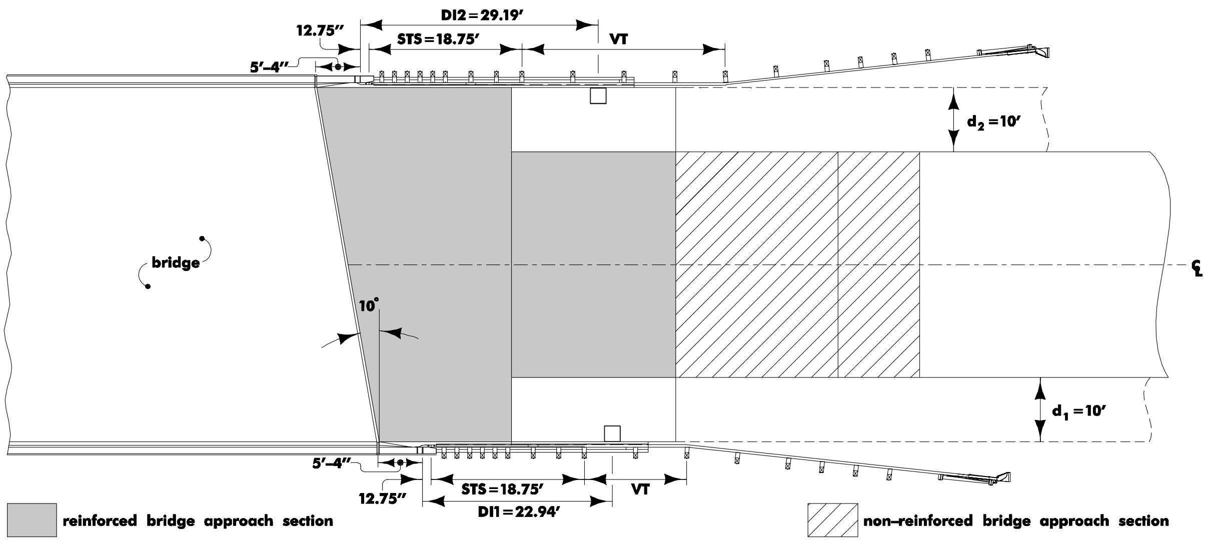


**Figure 2:** Location of the intakes.

DI1 = 12¾ in. + 18.75 ft. + 6.25/2 ft. = 22.94 ft.

DI2 = 12¾ in. + 18.75 ft. + 6.25 ft. + 6.25/2 ft. = 29.19 ft.

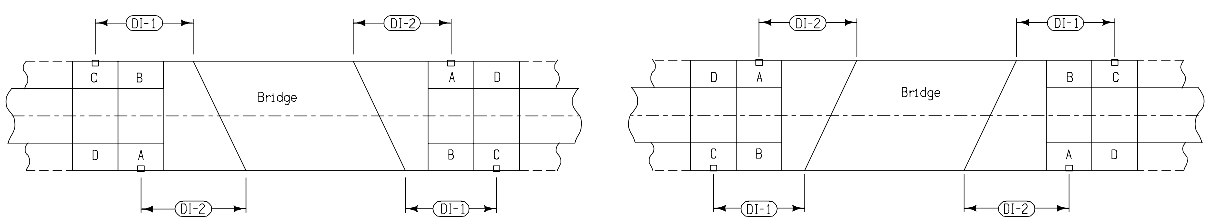


**Figure 3**: Panel locations**.**

Note: Figure 3 is taken from Standard Road Plan RF-38 (1) and shows the relative locations of panels A, B, C, and D with respect to the end of the continuously reinforced panel. When shoulders are not to be paved, shoulder panels are needed to accommodate intakes and meet the required 5-foot (1.5-meter) minimum distance from nearest joint.

Note: In the case of narrow bridge shoulders, 2 feet or 4 feet (0.6 meters or 1.2 meters), it may not be possible to locate an RF-38 end drain at the proposed location. Consider using an RF-40 end drain or drawing up the bridge/guardrail situation to locate the RF-38 end drain further from the bridge. Additional panels may be necessary.

## Determination of Grate Capacity

When using an RF-38, grate capacity is determined using the equation:

$$Q_I = KD^{5/3}$$

To determine K, go to Table 1 below. Using the longitudinal grade $S_L$ and cross slope $S_T$ , select the appropriate K value from the table.

**Table 1: K given $S_T$ and $S_L$.**

| $S_L$ \ $S_T$ | 0.00% | 1.00% | 2.00% | 3.00% | 4.00% | 5.00% | 6.00% |
|---|---|---|---|---|---|---|---|
| 1.00% | 29 | 23 | 19 | 17 | 15 | 14 | 13 |
| 2.00% | 39 | 31 | 25 | 22 | 19 | 17 | 16 |
| 3.00% | 43 | 34 | 28 | 25 | 22 | 20 | 18 |
| 4.00% | 47 | 37 | 31 | 27 | 24 | 22 | 20 |
| 5.00% | 54 | 40 | 33 | 28 | 25 | 23 | 22 |
| 6.00% | 56 | 42 | 35 | 30 | 27 | 24 | 23 |

To determine D, use the storm runoff $Q_R$ (see Section 4A-4) in combination with Tables 2, 3, and 4 to interpolate for D. Tables 2, 3, and 4 below provide values for D for flows of 1, 2, and 3 cfs. Tables 2, 3, and 4 are available for English units only. Designers using metric units will be required to convert $m^3/s$ to cfs to determine D. To do this, divide $Q_R$ in $m^3/s$ by $0.3048^3$: this will give $Q_R$ in cfs.

**Table 2: Values of D for $Q_R$ = 1 cfs.**

| $S_L$ \ $S_T$ | 0.00% | 1.00% | 2.00% | 3.00% | 4.00% | 5.00% | 6.00% |
|---|---|---|---|---|---|---|---|
| 1.00% | --- | 0.11 | 0.14 | 0.17 | 0.19 | 0.20 | 0.22 |
| 2.00% | --- | --- | 0.13 | 0.15 | 0.16 | 0.18 | 0.19 |
| 3.00% | --- | --- | 0.12 | 0.14 | 0.15 | 0.16 | 0.18 |
| 4.00% | --- | --- | 0.11 | 0.13 | 0.14 | 0.16 | 0.17 |
| 5.00% | --- | --- | 0.11 | 0.12 | 0.14 | 0.15 | 0.16 |
| 6.00% | --- | --- | 0.10 | 0.12 | 0.13 | 0.14 | 0.16 |

**Table 3: Values of D for $Q_R$= 2 cfs.**

| $S_L$ \ $S_T$ | 0.00% | 1.00% | 2.00% | 3.00% | 4.00% | 5.00% | 6.00% |
|---|---|---|---|---|---|---|---|
| 1.00% | --- | 0.14 | 0.19 | 0.22 | 0.24 | 0.26 | 0.28 |
| 2.00% | --- | 0.13 | 0.16 | 0.19 | 0.21 | 0.23 | 0.25 |
| 3.00% | --- | 0.12 | 0.15 | 0.18 | 0.20 | 0.21 | 0.23 |
| 4.00% | --- | 0.11 | 0.14 | 0.17 | 0.19 | 0.20 | 0.22 |
| 5.00% | --- | 0.11 | 0.14 | 0.16 | 0.18 | 0.19 | 0.21 |
| 6.00% | --- | 0.10 | 0.13 | 0.16 | 0.17 | 0.19 | 0.20 |

**Table 4: Values of D for $Q_R$= 3 cfs.**

| $S_T$ / $S_L$ | 0.00% | 1.00% | 2.00% | 3.00% | 4.00% | 5.00% | 6.00% |
|---|---|---|---|---|---|---|---|
| 1.00% | --- | 0.17 | 0.22 | 0.25 | 0.28 | 0.31 | 0.33 |
| 2.00% | --- | 0.15 | 0.19 | 0.22 | 0.25 | 0.27 | 0.29 |
| 3.00% | --- | 0.14 | 0.18 | 0.21 | 0.23 | 0.25 | 0.27 |
| 4.00% | --- | 0.13 | 0.17 | 0.20 | 0.22 | 0.24 | 0.25 |
| 5.00% | --- | 0.12 | 0.16 | 0.19 | 0.21 | 0.23 | 0.24 |
| 6.00% | --- | 0.12 | 0.16 | 0.18 | 0.20 | 0.22 | 0.23 |

Multiply K by $D^{5/3}$ to determine intake capacity.

Bypass is calculated by subtracting grate capacity $Q_I$ from storm runoff. If bypass is more than 10% of the storm runoff, a second intake may be needed.

## Example 3

Suppose $Q_R$ = 1.5 cfs (storm runoff), $S_T$ = 0.04, and $S_L$ = 0.05.

First find K using Table 1:

K = 25

Then find D using Tables 2 and 3 and interpolating:

1 cfs D=0.14

1.5 cfs D=0.16 (by interpolation)

2.0 cfs D=0.18

$Q_I$ = grate capacity = $KD^{5/3}$

$D^{5/3}$ = 0.0472 this is the flow intercepted by the grate

$Q_I$ =25 (0.0472) = 1.18 cfs

Bypass = $Q_R - Q_I$

Bypass = 1.50-1.18=0.32 cfs this is the flow that bypasses the grate

0.32 /1.50 =0.21 > 10 % allowable bypass is 10%

The allowable bypass should not exceed 10 %. Therefore, a second intake is needed downstream of the first intake to reduce the amount of bypass. The second intake should also be spaced according to the rules defined on pages 1 and 2 of this chapter. The second intake may be joined to a common storm sewer outlet.

If using metric units, convert $Q_R$ to cfs to determine D. For example, suppose

$Q_R$ = 0.05 $m^3$/s, $S_T$ = 0.04, and $S_L$ = 0.05

Again, use Table 1 to find K = 25

Now convert 0.05 $m^3$/s to cfs:

$0.05/0.3048^3$ = 1.77 cfs

Find D using Tables 2 and 3 and then interpolating:

1 cfs D=0.14

1.77 cfs D=0.17 (by interpolation)

2.0 cfs D=0.18

$Q_I$ = grate capacity = $KD^{5/3}$

$D^{5/3} = 0.0522$ this is the flow intercepted by the grate

$Q_I$ =25 (0.0522) = 1.31 cfs

Bypass = $Q_R - Q_I$

Bypass = 1.77-1.31 =0.46 cfs this is the flow that bypasses the grate

0.46 /1.77 = 26% > 10 % allowable bypass is 10%

Again, a second intake is needed downstream of the first intake to reduce the amount of bypass. To calculate $Q_I$ in $m^3/s$, simply multiply $Q_I$ in cfs by $0.3048^3$. For this example:

$1.31 \times 0.3048^3 = 0.037\ m^3/s$.